Conclusion: The Sentinel™ surface imaging device is a reproducible and consistent system able to detect misalignments with accuracy. This study shows good agreement between the surface scanner and CBCT in patient positioning. The Sentinel™ surface imaging system is a good supplement to the CBCT system for accurate set-up for fractions for whole breast irradiation after conservative surgery.

Poster Viewing : 4: Physics: Treatment planning: applications III

PV-0171

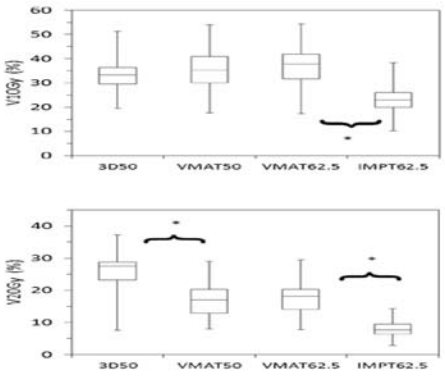
Can protons reduce bone marrow toxicity in definitive chemoradiotherapy for oesophageal tumours?

S. Warren[1], C. Hurt[2], T. Crosby[3], M. Partridge[1], M. Hawkins[1]
[1]*CRUK/MRC Oxford Institute for Radiation Oncology, Department of Oncology, Oxford, United Kingdom*
[2]*Wales Cancer Trials Unit, School of Medicine, Cardiff, United Kingdom*
[3]*Velindre Hospital, Velindre Cancer Centre, Cardiff, United Kingdom*

Purpose or Objective: Radiotherapy dose escalation using a simultaneous integrated boost (SIB) is predicted to improve local tumour control in oesophageal cancer patients (Warren IJROBP 2014), yet any increase in acute bone marrow toxicity could reduce treatment intensity, and limit any predicted improvement in patient outcome. In the SCOPE oesophageal trial, 28% of patients treated with concurrent cisplatin/capecitabine and 50 Gy in 25 fractions experienced grade ≥3 haematological toxicity (HT3+) (Crosby Lancet Oncol 2013). Proton therapy has been shown to significantly reduce haematological toxicity in lung cancer patients receiving concurrent chemotherapy (Komaki Radiother Oncol 2011); we investigate the potential of bone marrow sparing with protons compared to photons, in radiotherapy dose escalation for oesophageal tumours.

Material and Methods: 21 mid-oesophageal cancer patients with their original conformal plan (3D50) (chosen to be a representative subset of the SCOPE trial) were used to study the bone marrow dose delivered. A surrogate for bone marrow was created by outlining the thoracic vertebrae, sternum, scapulae, ribs and clavicles using the automatic thresholding tool in Eclipse (Varian). Additional plans were created retrospectively: a volumetric modulated arctherapy plan (VMAT50) with the same dose as 3D50. SIB plans with a dose prescription of 62.5 Gy to the high risk sub-region within the planning treatment volume were created using VMAT (VMAT62.5) and proton therapy plan (IMPT62.5). Bone V20 Gy and V10 Gy dose-metrics were recorded and compared across all plans using the Wilcoxon test and Holm Bonferroni correction for multiple testing. Parameters from gynaecological cancers (Bazan IJROBP 2012) were used to predict normal tissue complication probability (NTCP) of HT3+.

Results: 3D50 plans show the highest NTCP and V20 values for each patient. There is no significant difference between the VMAT50 and VMAT62.5 plans, although VMAT plans may cause a larger bone volume to be irradiated below 10 Gy than 3D50. IMPT62.5 showed significant sparing for both V10 and V20 and much reduced NTCP



Comparing V_{10Gy} (top) and V_{20Gy} (bottom) for the four different plans. Plots show median (horizontal bar), interquartile range (box) and maximum and minimum (capped lines) values across all patients, with statistically significant differences between plans marked *.

Conclusion: Proton therapy plans show significant dose sparing for bone marrow in the 10-20 Gy dose region thought to be correlated with toxicity. These plans are predicted to reduce the risk of HT3+ by ~50% compared to photon techniques, and could therefore improve treatment efficacy of concurrent chemoradiotherapy for oesophageal cancers.

PV-0172

Selecting patients with lung cancer for proton therapy should be based on multivariable NTCP models.

M.C.A. Kramer[1], A.G.H. Niezink[1], E.W. Korevaar[1], R.G.J. Kierkels[1], H.P. Van der Laan[1], A. Van der Schaaf[1], V.C. Hamming[1], P. Kalk[1], J.A. Langendijk[1], J. Widder[1]
[1]*UMC Groningen, Radiotherapy Oncology Department, Groningen, The Netherlands*

Purpose or Objective: The aim of the study was to evaluate how the dosimetric benefit of intensity-modulated proton therapy (IMPT) translates into estimated toxicity risk reduction in patients with locally advanced non-small cell lung cancer (NSCLC). In addition, the potential to spare the heart with protons and photons was explored.

Material and Methods: Five patients with NSCLC were treated with concurrent chemoradiation, using standard lung-sparing photon volumetric-modulated arc therapy (L-VMAT) to 60 Gy in 25 fractions. Three additional treatment plans were created for each patient: heart-sparing VMAT (H-VMAT), worst-case robust heart-sparing IMPT (H-IMPT), and worst-case robust lung-sparing IMPT (L-IMPT). Doses to the organs at risk (heart, lung) were evaluated. Resulting normal tissue complication probability (NTCP) values for radiation pneumonitis were estimated using the dose-only QUANTEC model and the adjusted QUANTEC model including clinical risk factors 1.

Results: With IMPT, both H-IMPT and L-IMPT, DVH parameters including the mean lung dose (MLD), the lung volume receiving ≥20 Gy (V20L), the mean heart dose (MHD), and the volume of the heart receiving ≥30 Gy (V30H) were all between 32 – 80% lower compared with L-VMAT (Tab 1). Furthermore, at these considerably lower dose levels with protons vs photons, the amount of dose redistributed to the lungs when the heart was particularly spared was still lower with protons (H-IMPT vs L-IMPT: 65% decrease MHD, 11% increase MLD), compared with photons (H-VMAT vs L-VMAT: 62% decrease MHD, 28% increase MLD). Using the dose-only QUANTEC model, comparing L-VMAT with L-IMPT, the lung-dose reductions translated into a reduction in the risk of symptomatic radiation pneumonitis between 4.5% to 9.2% (average, 5.8%). However, the QUANTEC model adjusted for a priori clinical risk factors showed a reduction of symptomatic radiation pneumonitis risk in patients without clinical risk factors by 2.5% to 5.4% (average, 3.3%) in contrast to 14.2% to 26.7% (average, 18.2%) risk reduction in patients with the highest a priori risk (Fig 1). For identical DVH reductions, and assuming a threshold risk reduction of≥ 10% for G2-toxicity required for indicating proton therapy, an

actual indication for protons thus heavily rests on individual clinical and patient dependent a priori risk factors.

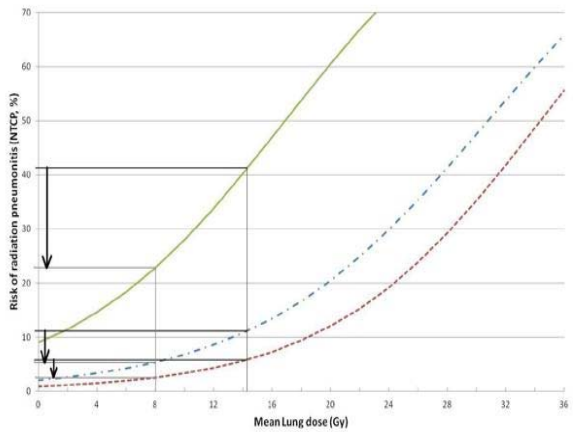
Table 1.

Dosimetric parameters for lung and heart for the different techniques and corresponding NTCP for symptomatic radiation pneumonitis (values in Gy or %).

	H-VMAT	L-VMAT (reference)	H-IMPT	L-IMPT
MeanLungDose	18.3±2.6	**14.3±1.9**	8.9±2.1	8.0±2.3
V20 Lung	34.7±4.2	**25.0±2.7**	17.0±4.0	14.8±4.4
MeanHeartDose	9.9±3.1	**15.9±2.9**	3.2±1.1	4.9±1.1
V30 Heart	10.1±5.9	**19.1±2.9**	4.3±2.0	7.1±2.1
Risk of radiation pneumonitis				
QUANTEC_dose only	17.7±4.5	**11.4±2.4**	6.2±1.7	5.6±1.6
QUANTEC_low clinical risk[1]	10. 1±1.4	**6.0±1.5**	3.0±0.9	2.6±0.9
QUANTEC_high clinical risk[1]	54.8±6.1	**41.2±6.2**	25.3±5.7	23.0±5.8

Figure 1.

Estimated NTCP value reductions (arrows) for symptomatic radiation pneumonitis for low (red line) and high (green line) a priori risk patients and patients irrespective of a priori risk factors (blue lines). Marked are the estimated risk reductions of symptomatic radiation pneumonitis for lung-sparing IMPT (grey lines) versus lung-sparing VMAT (black lines).



Conclusion: These results demonstrate that the potential of proton therapy to reduce the risk of radiation pneumonitis requires considerable reduction in lung dose, but translation into clinical significance is heavily driven by patient and clinical a priori risk factors. Therefore, multivariable NTCP models should play a major role in identifying patients eligible for proton therapy.

1 Appelt, Vogelius, Farr, Khalik, Bentzen. Towards individualized dose constraints: adjusting the QUANTEC radiation pneumonitis model for clinical risk factors. Acta Oncologica 2014;53:605.

PV-0173

Dosimetric assessment of three-source Co-60 and Linac-based lung SBRT for feasibility of MR-IGRT

N. Dogan[1], N. Lamichhane[1], A. Ishkanian[1]

[1]*University of Miami- Sylvester Comprehensive Cancer Center, Department of Radiation Oncology, Miami- Florida, USA*

Purpose or Objective: The purpose of this study is to provide a dosimetric assessment for the feasibility of delivering lung SBRT using an integrated three-source Co60 and Magnetic Resonance Imaging (MRI) Guided Radiation Therapy (MR-IGRT) System.

Material and Methods: Ten lung patients who were previously treated with Linac-based SBRT were included. For each patient, GTV, PTV, cord, lungs, heart, esophagus, and ribs were delineated. All Linac-based SBRT plans were generated using VMAT and consist of 2-10 6MV Rapid Arcs. Patients received prescription doses of 48 Gy/4fx to 50 Gy/5fx. The Linac-based plans were imported into the View Ray MR-IGRT system for planning. Three-source Co60 plans were generated using step-and-shoot IMRT and utilized Monte Carlo dose calculation including the magnetic field correction of 0.35T. The PTV coverage for both Linac-based three-source Co60 SBRT plans were such that 95% of the PTV received 100% the prescription dose. Finally, Linac- and three source Co60 – based plans were evaluated using dose-volume constraints for critical structures and target conformity index (CI), homogeneity index (HI) for the PTV.

Results: The differences between PTV HI for Linac- and three-source Co60 -based SBRT plans were not statistically significant, ranging from 1.05 to 1.15. Three patients with the CIs >1.2 had target volumes <20cc although the location of the target did not have much influence on meeting the criteria for the target conformity. For all patients, the critical structure doses, such as maximum cord dose (<26 Gy), dose to <15 cc of the heart (28Gy<15cc), and <5cc of the esophagus (18.8 Gy<5cc) were satisfactory with both techniques. For lung, although both the dose to <1500cc (11.6 Gy<1500cc) and <1000cc (13.6Gy<1000cc) criteria were met with both techniques, on average, the lung volumes receiving the 11.6Gy and 13.6Gy were 59.5% and 61.28% higher with three-source Co60 as compared the Linac-based SBRT plans respectively (P<0.05). As expected, low dose portion of the DVH for all critical structures generally covered much higher percentage of the critical structure volumes with three-source Co60 SBRT plans as compared to the Linac-based SBRT plans.

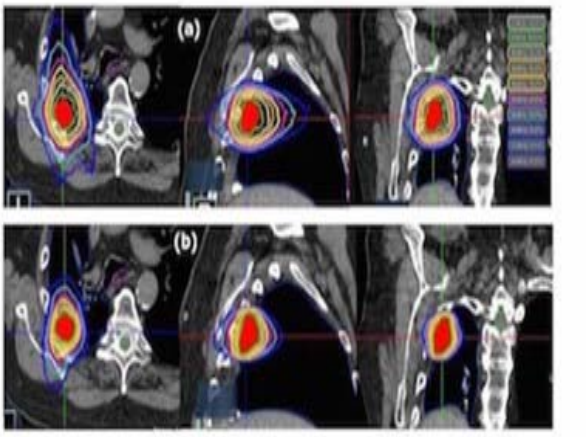


Figure 1: Dose distributions in axial, sagittal and coronal slices obtained with (a) three-source Co^{60} MR-IGRT system (View Ray, Inc.) and (b) 3 Rapid Arcs (Varian Eclipse) for one of the lung SBRT cases included in this study (Prescription Dose: 50 Gy/5 fx, green isodose line).

Conclusion: Overall, a three-source Co60 integrated MR-IGRT system produced comparable dose distributions to the ones obtained with the Linac-based lung SBRT. Further studies are needed to evaluate benefits of this novel MR-IGRT system for lung SBRT, especially its ability to image and plan in real time and online adaptive treatment delivery.

PV-0174

Experimental verification of 4D Monte Carlo calculations of dose delivered to a moving anatomy

J. Cygler[1], S. Gholampourkashi[2], J. Belec[1], M. Vujicic[1], E. Heath[2]

[1]*The Ottawa Hospital Regional Cancer Centre, Medical Physics, Ottawa, Canada*

[2]*Carleton University, Physics, Ottawa, Canada*

Purpose or Objective: To experimentally validate a 4D Monte Carlo (MC) simulation method to calculate the dose